A DEEP OCEAN NEPHELOMETER

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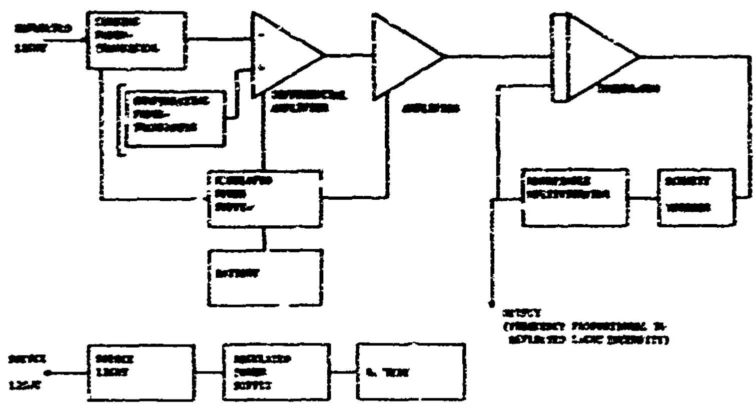

Figure 1. System Block Diagram.

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ABSTRACT

An experimental nephelometer is described that is compact, independent of ambient temperature, easily deployed, battery operated, and capable of giving continuous *in situ*, real time measurements of turbidity in the deep ocean. The instrument has constant light intensity and gives repeatable readings under experimental conditions.

INTRODUCTION

Oceanographic surveys have shown strong evidence of migratory suspended matter in the deep ocean that are of great interest to the oceanographer (Ewing and Thorndike, 1965). Real time detection of such nepheloid layers has not been perfected. Most systems in use are camera systems such as the one described by Ewing, Hunkins, and Thorndike (1969) which require retrieval for data processing. Other systems use photovoltaic cells or photomultiplier tubes with inherent problems of non-linearity of the first and gain shift with time of the second (Jerlov, 1968).

The instrument described herein embodies the techniques of miniaturized electronics and employs phototransistors and operational amplifiers to achieve a measure of stability greater than in previous instruments which utilize more conventional components. Real time, *in situ* location of turbidity layers allows more meaningful sampling since samples can be collected at the instant of detection. Also, the feasibility of using other optical systems, such as cameras, can be determined if the degree of turbidity is known. The instrument is compact, light weight, battery powered, insensitive to ambient temperature, capable of locating nepheloid layers in the deep ocean and measuring their degree of turbidity.

The nephelometer described uses back scattered light as a measure of the amount of suspended matter in water.

DESIGN

Two general problems associated with optical reflectance meters have been addressed in the design of this instrument. These problems are the adverse effect of ambient temperature changes upon the stability of the instrument, and the lack of a real time measurement capability for deep ocean operations.

Most electronic devices and power sources are affected to some degree by ambient temperature changes. To prevent appreciable system dependence upon these changes, compensating and power supply regulating circuits have been employed in the nephelometer described.

The source of illumination is self contained in the instrument package. It consists of a modified aerial gunsight used as a collimator. The source is powered by a regulated power supply so that changes in battery voltage due to discharge and temperature do not affect the output intensity of the light source. Opalized glass is inserted immediately beyond the light bulb of the light source to eliminate filament images. The light bulb produces approximately 24 watts of power and is the only source of

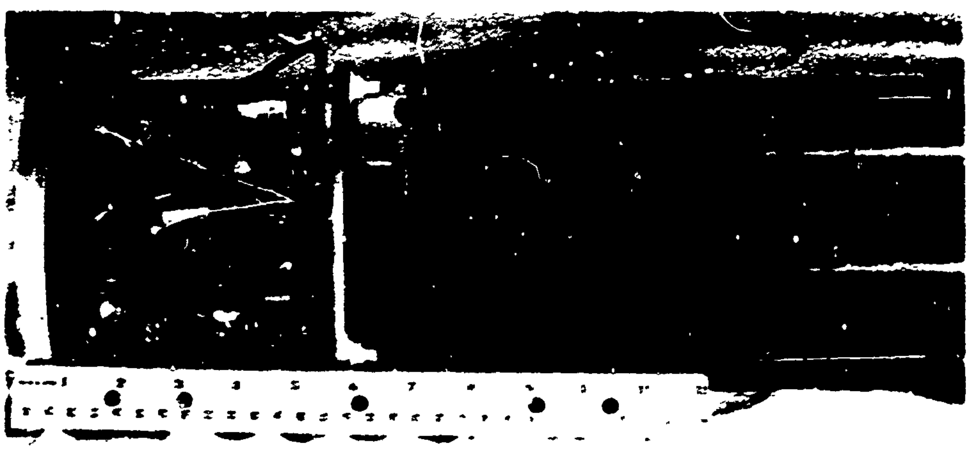

Figure 2. Nephelometer removed from pressure case. The battery pack is on the right.

reflected light when the instrument is used beyond ambient light levels.

To negate temperature effects on the light sensor, two phototransistors have been mounted adjacently in the aluminium face plate of the instrument. One of the phototransistors faces the ocean medium and detects the amount of light from the collimated light source which is back scattered. Its output voltage is dependent on the amount of light reflected back from suspended material in the ocean and any temperature effects. The second phototransistor is shielded from all light and its output voltage is a function of temperature effects only. Since the phototransistors are mounted in close proximity they are always at the same temperature and any voltage change due to temperature can be compensated by subtraction of the two output voltages. The output voltage of the phototransistors changes approximately 0.667 percent per degree Centigrade (Bliss, 1968). The subtraction and amplification of the two voltages is accomplished by an operational amplifier in a differential configuration. The sensing phototransistor is connected to the inverting port of the operational amplifier while the temperature compensating signal is fed into the non-inverting port. The inputs to the amplifier have been adjusted to the same gain. Thus, temperature dependence has been cancelled and the output of the amplifier is an inverted signal that is proportional to the back scattered light only. The output of the amplifier is increased in magnitude and inverted using a second operational amplifier. The output of the second amplifier depends only on the amount of back scattered light incident on the sensor and is independent of environmental temperature variations. To further reduce any possibility of temperature effects, regulated power supplies are used to power the operational amplifiers

In order to provide real time measurement capability, the output of the second amplifier is connected to an operational amplifier in a summing, integrator configuration. The integrated signal is connected to a Schmitt trigger which is connected to a monostable multivibrator. The output of the multivibrator is opposite in sign to that of the input to the integrator. The multivibrator is connected to the input of the integrator. When a dc voltage is applied to the integrator, a ramp function is generated which has a slope that is directly proportional to the amplitude of the dc input voltage. When the ramp function reaches a preset amplitude the Schmitt trigger turns the multivibrator "on." The output of the multivibrator returns the output of the integrator to zero. The period of the resulting signal, from the multivibrator, is proportional to the amount of back scattered light incident on the sensing phototransistor. Since the frequency of the pulses is measured, and not the amplitude of the signal, the signal can be transmitted over long cable lengths. The block diagram of the nephelometer is shown in Figure 1. Figure 2 shows the nephelometer removed from the pressure case. A close up of the circuit boards is shown in Figure 3.

No universal calibration procedure has been established for reflectance meters. Calibration is relative due to the non-uniformity (materials and size) of the particles being detected (Sheldon and Parsons, 1969). As a result, simulated turbidity has been used so that the sensitivity of the instrument can be accurately reproduced. Three galvanized screens of different mesh sizes were used to simulate degrees of turbidity. The screens were placed six inches in front of the instrument pressure face plate (plexiglas, six inches in thickness) and reflectance reading taken. The test was performed in fresh water in a 3 by 6 by 2 foot tank with black, non-reflecting surfaces. The finest mesh screen

Figure 3. Nephelometer circuit boards separated from battery pack; phototransistors are mounted in base plate. The light source is behind the two circuit boards.

corresponded to the highest turbidity while the other two meshes simulated relatively less turbid conditions. Results of the sensitivity measurements are shown in Table I.

The instrument was tested for temperature dependence by placing it, while at room temperature, in an ice water bath (3'x6'x2') and monitoring the output of the second amplifier as the instrument cooled. The incident reflected light level was controlled during this test. The temperature test simulated the effect of lowering the instrument into the ocean where it would experience a varying temperature gradient. The output of the second amplifier varied between 19 and 21 millivolts. Since a digital voltmeter was used the variation of plus or minus one digit about 20 millivolts is attributed to the voltmeter's least significant digit rather than actual temperature drift. Complete results of the test are shown in Table II. The temperature of the nephelometer was recorded at the heat sink near the sensing circuit board.

The system described is not designed for use in intense light situations and in such cases will drive to maximum output and latch until the light level is reduced. Additionally, the sensors cannot discriminate between ambient light and reflected light as the instrument has been designed for use in the deep ocean beyond ambient light levels.

TABLE I

CALIBRATION

Condition	Average output MV
Dark	0
1/16" mesh galvanized screen reflector-- fine wire	112
1/4" mesh galvanized screen reflector-- coarse reflector	58
3/4" hexagonal mesh "chicken" wire-- fine wire	22

NOTES:

1. Noise level ±1 MV typical.
2. Screens placed 6 inches in front of face plate (12 inches in front of phototransistor).

TABLE II

SYSTEM TEMPERATURE DEPENDENCE

Elapsed Time Minutes	Instrument Temperature °F	Water Bath Temperature °F	Reflection Output From Low Level Backscatterer MV
0	72	36	21
9		37	21
19		37	20
30		38	20
40		37	21
67		38	19
87		39	19
123		40	19
144	40	40	20

NOTES:

1. Instrument temperature measured on heat sink near printed circuit board.
2. Temperature differential, -32°F.
3. Dark output was measured at ±1 MV.

CONCLUSIONS

It was observed that the instrument is relatively insensitive to temperature. For example, if a coarse screen (see Table I) is used as a measure of sensitivity, in a temperature range of 72 to 40°F, the output changes only 0.14 percent per degree Fahrenheit. As previously discussed this change is attributed to the digital voltmeter rather than the instrument. Since the instrument is designed for use in deep ocean areas where large temperature variations do not normally exist, for practical purposes, the instrument is not sensitive to temperature.

Additionally, the output of the system is not affected by cable lengths between the instrument and the oceanographic survey vehicle. Thus, real time recording of back scattered light is possible.

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